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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

10/6 Yearly. THE JOURNAL OF SCIENTIFIC ILLUMINATION. 1/- a Copy.

OFFICIAL ORGAN OF THE
Illuminating Engineering Society.
(Founded in London 1909.)

This number contains the Paper entitled ***"The Effect on the Eye of varying degrees of Brightness and Contrast"*** read by ***Dr. James Kerr*** at the last meeting of the Illuminating Engineering Society on February 20th, and the ensuing Discussion; special reference being made to ***Conditions of Illumination in Cinematograph Theatres.*** Some additional contributions on ***"The Lumen as a Measure of Illuminating Power,"*** by ***Mr. A. P. Trotter, Prof. A. Blondel*** and others are also presented.

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EDITORIAL.

The Effect of Contrast on Vision.

The discussion opened by Dr. Kerr's paper at the last meeting of the Illuminating Engineering Society, with which we deal in the present number (pp. 39—58) raised a number of interesting points, notably the effect on the eye of extreme contrast in brightness. The question of glare, as Dr. Kerr pointed out, formed the subject of one of the earliest discussions of the Society in 1910, but since then there have been a number of researches which have considerably enlarged our knowledge of the effect of glare on the eye.

One point, emphasised in recent discussions of the American Illuminating Engineering Society, is the importance of *contrast*. It is now accepted that it is not enough merely to define the absolute brightness of luminous objects within the field of view. To aim, for example, at a maximum brightness of 3 candles per square inch (the average brightness of the white sky) may be a useful principle, but it is necessary also to bear in mind the state of the eye, when observing this object, as affected by the brightness

of surroundings, or its previous experience. In fact, the degree to which a luminous object may appear glaring depends on the state of adaptation of the eye.

As a tentative step towards the specification of these conditions, Dr. Kerr recalls the suggestion that the ratio of brightness in the field of vision should preferably not exceed 100 : 1. In recent discussions of the Society there have been several illustrations of the effect of great " simultaneous contrast " in which this ratio may be exceeded. For example, in rifle range lighting experience showed that an extreme contrast between the brightly lit target and the relatively dark surroundings is undesirable. Again, in the conditions recently prevailing in the streets (but now happily being modified in accordance with the latest regulations of the Authorities), the sudden transitions from bright patches of light under the lamps to complete obscurity in the more remote parts of the street were generally recognised to be highly inconvenient and distracting to drivers and pedestrians.

Such extreme contrasts may be prejudicial when both the bright area and the dark area are simultaneously visible, as, for example, in the case of rifle range lighting mentioned above, or in the case of strong local lighting in an office or factory with relatively little general illumination. But they are equally objectionable when the change is brought about successively by a person passing from a dark area to a very brightly illuminated one, or vice versa. The distraction caused by such changes might quite possibly lead to accidents, the eye, in its unadapted state failing to perceive steps, moving vehicles, etc.

It is therefore desirable that in public buildings the contrast between the lighting in halls and vestibules should not be excessive. There should be a gradual transition from the interior to the exterior conditions.

Readers must be referred to Dr. Kerr's Paper for the analysis of the construction and functions of the eye, and their relation to its experiences of glare. It is evident that there is room for a great deal of research in establishing the conditions of contrast most favourable to vision. The suggested ratio of 100 : 1 for the maximum contrast desirable appears to rest mainly on practical experience ; it would be extremely useful if a series of researches could be carried out in the laboratory to corroborate this suggested ratio. Some experiments in this direction have been made in the United States, but the work might well be confirmed and extended in this country. Another matter deserving of study is the degree of flicker which is appreciable to the eye, with a view to specifying the desirable " steadiness " of a source of light. Yet another question is the relation of these factors to the conditions in cinema theatres, to which special reference was made in Dr. Kerr's Paper.

Conditions of Illumination in Cinema Theatres.

The discussion on this subject at the last meeting of the Society was timely in view of the investigation now being conducted by the Cinema Commission, two members of which, Dr. C. W. Kimmins (Chief Inspector of Schools to the London County Council), and Mr. A. E. Newbould (Cinematograph Exhibitors Association), were present, and officially invited the Society to form a small committee to co-operate with the Commission in examining the lighting conditions in cinema theatres, and to report upon any improvements, to be observed, if possible, throughout the country.

This proposal was welcomed by Mr. Goodenough, the Chairman of Council of the Society and supported by the Hon. Secretary.

Conditions in cinema theatres afford an interesting instance of the need for co-operation between different experts. Seeing that such displays cater entirely for the eye the peculiarities of this organ require careful study by oculists and physiologists. On the other hand, the conditions of lighting which give rise to healthy or harmful effects require investigation by lighting experts. Nor must it be forgotten, as the President remarked, that the eye is an " off-shoot " of the brain, so that harmful impressions received by the eye may react on the brain and lead to injury in other directions.

Films depicting incidents of an exciting and vivid character may be unsuitable for young children, and in any case should not form intervals in an educational programme which require calm and continuous mental effort.

Even for adults the above considerations are of importance. In the case of children, whose eyes, brain, and physical conditions generally are in a state of development, and therefore easily harmed, the matter is of special importance, especially in view of the educational possibilities of the cinematograph and its potential wider use in schools.

That the conditions of vision in a cinema hall are abnormal in several respects, is evident. The eye is gazing constantly in a fixed direction at a highly luminous screen, with relatively dark surroundings and extreme contrast. The projection of pictures, even in the best conditions, is attended with a certain degree of flicker and fluctuations in light, which may be accentuated by imperfections in the film, lantern, or screen, or a combination of such defects or by unsatisfactory conditions of illumination. In any case there is a certain strain on the minds of children in receiving the rapidly following impressions, and it has therefore been suggested that the duration of entertainments for young people should be limited and that special measures, in the form of preliminary explanations, should be taken to make the subject of the film readily understood. Among other matters calling for investigation are the desirable distance of observers from the screen, the provision of a moderate general illumination in the auditorium designed to lessen contrast and yet not impair the image on the screen, and the graduation of illumination in vestibules and corridors with a view to lessening the sudden transitions in brightness and darkness in passing from the hall to the street outside. Needless to say any bright unscreened lights liable to cause distraction and glare in the auditorium should be avoided, and measures should preferably be taken, by the use of dimmers, etc., to reduce or increase the illumination gradually when a film is ended or commenced.

All these are matters which would well repay investigation and no doubt the Committee of the Illuminating Engineering Society will be able to make suggestions which will be of genuine public benefit.

Street Lighting and Accidents.

When the diminution in street lighting was first undertaken, shortly after the outbreak of war, we foresaw that unless this darkening was carried out on scientific lines, it might lead to inconvenience to traffic and an increase in accidents. At the first meeting of the Illuminating Engineering Society held on Dec. 1st, 1914, attention was drawn to the objectionable contrasts in light and shade resulting from the methods of screening employed, and it was suggested that attempts should be made to secure more even distribution of light. Shortly afterwards, in an editorial on the same subject, it was remarked that an increase in street accidents, partly attributable to the lighting conditions was already becoming apparent.

The results of two years experience were summarised in the discussion before the Illuminating Engineering Society on December 15th last year. Statistics were quoted, indicating a progressive increase in street accidents since the outbreak of war, but it was pointed out that fuller details were needed in order that the effect of the diminished lighting might be clearly traced. In particular, it was desired that the accidents should be given for each month, and a division made between those occurring respectively by day and by night.

Some interesting figures have since been given for the metropolitan area, a classification by day and night now being made, although only the total casualties in each year were stated, and not the number each month. These figures are as follows :—

Year.	Killed.				Injured.			
	Day.	Night.	Percentage increase from 1913 to 1915.		Day.	Night.	Percentage increase from 1913 to 1915.	
1912	461	77			17122	3044		
1913	518	90	Day.	Night.	20380	3385	Day.	Night.
1914	523	116	34%	73%	21554	3916	6%	21%
1915	695	156			21755	4112		

An examination of these figures shows that while there has been apparently a tendencey for all accidents to increase, the rise has been proportionately much greater by night than by day. They therefore afford evidence that the diminished lighting, which began in 1914, but was carried on continuously throughout 1915, was an influential factor. Possibly, if the figures of 1916, and particularly the dark winter months, were available, the results might be yet more striking. For example, Dr. Ingleby Oddie, the Lambeth Coroner, recently stated that the number of fatal accidents coming under his notice had increased from 17 in October, November, and December, 1913, to 47 during the corresponding period of 1916.

The question of street lighting in relation to accidents is now receiving attention from a sub-committee of the London Safety First Council, on which the Illuminating Engineering Society is represented. It is satisfactory to know that a record is being kept of changes in lighting and their effects, and after the cessation of hostilities the experience now being gained will no doubt provide a very valuable subject for discussion at the hands of the Illuminating Engineering Society.

LEON GASTER.

TRANSACTIONS

OF

The Illuminating Engineering Society.

(Founded in London, 1909.)

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

THE EFFECT ON THE EYE OF VARYING DEGREES OF BRIGHTNESS AND CONTRAST.

(Proceedings at a meeting of the Society held at the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 5 p.m., on Tuesday, February 20th, 1917.)

A MEETING of the Society took place as stated above, on Tuesday, February 20th, at 5 p.m., the chair being taken by the President (Sir William Bennett, K.C.V.O.).

The minutes of the last meeting having been taken as read, the HON. SECRETARY read out the names of the following applicants for membership :—

Ordinary Members :—

Campbell, J. B.	Assistant Electrical Engineer, Public Works Department, Sydney, NEW SOUTH WALES.
Luckhurst, T. W.	Secretary, Weston-super-Mare Gas Light Co. (Bracewell, Milton Road, WESTON-SUPER-MARE.)

Corresponding Member :—

Hammer, W. J.	Consulting Electrical Engineer, 55, Liberty Street, NEW YORK CITY, U.S.A.

Honorary Member :—

Blondel, Prof. A.	41, Avenue de la Bourdonnais, PARIS. (*In recognition of distinguished services to the study of illuminating engineering in France.*)

The HON. SECRETARY, referring to the nomination of Prof. A. BLONDEL as one of the Honorary Members for the current year, said that Prof. Blondel's services to illuminating engineering in France were known and valued by all who were engaged in the study of this subject. He had been one of the very earliest pioneering workers in this field, and his name was associated with many important scientific investigations. Prof. BLONDEL had taken a deep interest in the work of the Society, and this was an opportune moment to express its appreciation of his distinguished services.

Mr. HAMMER, who had been nominated a Corresponding Member, was one of

Mr. Edison's original assistants, and had been closely associated with the early development of the electric incandescent lamp, as well as with scientific work on phosphorescence and fluorescence.

The HON. SECRETARY also read out again the names of those applicants for membership nominated at the last meeting of the Society,* and these gentlemen were formally declared members.

The PRESIDENT then called upon Dr. JAMES KERR to read his paper on "The Effect on the Eye of Varying Degrees of Brightness and Contrast" (see pp. 41-49).

In opening the discussion on the subject the PRESIDENT remarked that many of the points dealt with by Dr. KERR were of very great importance in relation to lighting problems, and he had dealt in a very lucid and interesting manner with the many curious phenomena characteristic of the eye when adapted to strong and weak illuminations. The section of the paper dealing with conditions in cinematograph theatres was of special importance. He thought there was some danger that those who were concerned with the moral influence of such exhibitions on children might overlook the possibility of physical injury. The eye was a highly sensitive organism, and when in process of development was particularly susceptible to overstrain. It was therefore most important that the conditions prejudicial to the eyesight of children should be studied and precautions taken against any possible sources of injury.

An interesting discussion then took place in which the following took part:—

Mr. J. W. BARBER, Mr. J. G. CLARK, Mrs. CLOUDESLEY BRERETON, Mr. A. CUNNINGTON, Mr. J. S. DOW, Dr. F. W. EDRIDGE GREEN, Mr. L. GASTER, Mr. F. W. GOODENOUGH, Dr. C. W. KIMMINS, Lieut. S. R. MULLARD, R.N.V.R., Mr. A. R. NEWBOULD, Mr. E. T. SWINSON, and Mr. A. P. TROTTER.

The ASSISTANT HON. SECRETARY also read a number of letters from various members of the Cinema Commission, regretting their inability to be present, but expressing interest in the discussion, and written contributions from Dr. ERNEST CLARK, Mr. N. BISHOP HARMAN, Mr. COLIN BENNETT, and Mr. E. G. KENNARD, were read.

Dr. C. W. KIMMINS (H.M. Chief Inspector of Schools) and Mr. A. E. NEWBOULD (Chairman, Cinematograph Exhibitors' Association), speaking on behalf of the Cinema Commission, expressed their interest in the problems raised in the paper and conveyed to Dr. Kerr an invitation to give evidence before the Commission. The hope was also expressed that the Society would nominate a small committee to co-operate with the Commission in determining the best conditions of illumination and other factors of importance in relation to eyestrain.

Mr. F. W. GOODENOUGH (Chairman of Council) expressed the appreciation of the Society of this invitation which would be brought before the Council at their next meeting. The Society would be only too glad to be of assistance in this matter.

At the conclusion of the discussion a vote of thanks was given to Dr. KERR for his paper. The PRESIDENT announced that the next meeting would take place at **5 p.m.** on **Thursday, March 22nd,** when a discussion on "**Phosphorescence and Fluorescence,** and their use to produce Luminous Effects," would be opened by **Mr. F. Harrison Glew.**

* *Illuminating Engineer*, January, 1917. p. 5.

EFFECT OF CONTRAST IN VISION.

The most recently received number of the Transactions of the Illuminating Engineering Society, U.S.A. (No. 9, Vol. XI., Dec. 30th, 1916), contains several items:—"Effects of Brightness and Contrast in Vision," by P. G. Nutting; "Apparent Brightness: its Conditions and Properties," by L. T. Troland; "The Effect of Brightness of Light Sources on General Illumination," by F. C. Caldwell, which deserve study in connection with the points raised in Dr. Kerr's paper.

THE EFFECT ON THE EYE OF VARYING DEGREES OF BRIGHTNESS AND CONTRAST.

By Dr. James Kerr (Public Health Department, London County Council).

(Paper presented at a meeting of the Society, held in the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 5 p.m., on Tuesday, February 20th, 1917.)

I wish to-night to take a very simple glance at illumination from the point of view of the work called for from the eye, and therefore will confine myself to indicating a few topics of interest which seem to deserve discussion.

Almost the first of the Society's proceedings in its initial session in 1909—1910 was to send out a set of questions dealing with the subject of glare. It was difficult to assign any kind of definite answer to many of these questions, but since then we have travelled far.

The discussion which ensued opened up a variety of topics and was followed by other discussions or Reports of Committees. Whilst in some cases rules have been formulated and regulations suggested, others are waiting a satisfactory solution either because this would require time and money expended in actual laboratory researches which we have not at present the opportunity of carrying out or else because there is wanted time for the filtering of knowledge, and permeation beyond technical circles to bring about legislative changes and regulations.

The subject of glare put in the forefront of the Society's activities has enormous practical bearings, and the corresponding Society in America is doing much work to co-ordinate theoretical knowledge with practical usefulness.

One may not hit a man on the comparatively insensitive skin without running the risk of legal or other penalties, but may with impunity, literally hit him in the eyes with a thousand candlepower beam. Short, however of this, the effects of glare are daily felt and far-reaching.

Lighting belongs to the amenities of life, and can be made an artistic pleasure if scientifically used but can be the very reverse by becoming a vulgar intrusion or glaring disturbance.

Individuals differ much in their reactions. A healthy muscular labourer could endure hours of lighting conditions, without remark, which in a sensitive, less well nourished, or possibly chronically fatigued worker might be the cause of lasting distress or ill-health.

Before proceeding to some practical examples of such effects. I propose to sum up the simplest physiological aspects of vision which should be kept in mind if the art of illumination is to be made a pleasure instead of an infliction.

While much of this information may appear elementary to those acquainted with opthalmology, it seems desirable, for the benefit of those concerned rather with the practical aspects of light, to make a few remarks on this subject.

Fundamental Properties of the Eye.

The psychology of the subject has to be remembered. The intellect builds up conceptions from past memories, and the merest hints of present things, and is easily deceived by ocular tricks, not only form, space, colour and distance, but of meaning and interpretation.

These physical judgments too are remarkably at fault in unaided estimates of quantity or quality of lighting.

It had been known for a couple of generations that the eye had great power of adjustment in relation to light. A power called *adaptation*.

The Importance of "Adaptation" in the Eye.

Adaptation has scarcely been sufficiently allowed for in practice, and was not put forward clearly as the essential factor in differences of lighting as for instance natural and artificial, till the discussion on glare took place.

At that time I had the idea that the range of adaptation, measured by the sensitiveness the eye attained in the dark was twenty or thirty times its sensitiveness in daylight. This estimate has been continually raised by almost every worker in the last half dozen years, and in the Report* published by a Committee of the American Society during the past year they state "Visual sensibility is fully a million times as great after half an hour rest in darkness, as in broad daylight."

This adaptation of the eye for light depends on a mechanism in the retina. The retina in which the image of the visual field is formed consists of a sheet of nervous tissue, really an outgrowth of the brain. The light penetrates this to about the depth of a fifth of a millimetre to reach the sensitive layer of rods and cones, which layer is itself backed by the layer of black pigment cells. This last layer not only prevents irregular dispersion and reflection but also acts as the chief machinery in the light *adaptation* of the eye.

In passing it may be remarked that *adaptation* of the retina, is quite distinct from *accommodation* of the eye by the lens as these terms are used in ophthalmology. The distinction should be maintained, although accommodation is occasionally used where adaptation is meant.

The Retinal Structure.

To understand this adaptation we must know a little more of the retinal structure. From within where the light first strikes it, there are several layers of nerves and nerve cells, making up about nine-tenths of its thickness; these have to be penetrated by the light, then comes sharply defined the layer of rods and cones. This layer is shown to be the sensitive region because the only spot where it is absent, at the entrance of the optic nerve, is quite blind, the blind spot, big enough to take a penny on a sheet of paper at a foot distance. The rods and cones are somewhat cylindrical bodies, standing endwise on to the light, and roughly consist of an inner more swollen half and an outer thin and transversely striated part, the outer end of which abuts on the pigment layer. From the pigment layer fine prolongations of the pigment containing cells extend up between the rods.

If no light has been falling on the retina for some time, as for instance in an animal kept in the dark, the pigment granules in the cells form a thin layer, dense and black, just touching the outer ends of the rods.

If however the eye has recently been exposed to light so that the retina is adapted thereto, the prolongations or processes of the cells running up between the rods are filled with the black pigment granules. They not only help to absorb light, but are probably actively engaged in renewing a photosensitive material the so-called visual purple, contained in the rods. When the rods are highly charged with this, and light has full access to them, as in the dark adapted eye, they appear exquisitely sensitive to the slightest variation, but when this purple material is largely used up, and the light greatly damped by the migrated pigment granules, the rods are seemingly much less sensitive, a million times less as the recent Report says.

The cones already mentioned are thicker and shorter and very many fewer than the rods. One observer estimated seven million cones and 130 million rods in the adult. Towards the periphery the rods become fewer and the cones disappear.

At one part of the retina, all the layers thin out, and at last disappear except the cones. This is the little central area known as the *macula*, and the centre of that with only big cones, is known as the *fovea*. It is the area of greatest distinctness of vision. This area is perhaps half a millimetre across, and the whole macula one to two millimetres. This part is the real eye which is used for exact knowledge the rest of the retina giving indications or hints to orient the exact sensations at the macula. For this reason the rest of the retina is sensitive to movements of light or shade or to the merest flicker but not to form. Some think that the rods merely distinguish light, whilst the cones analyse form and colour.

It is the macular vision which is so enormously important, and which reacts to fatigue and poisons. With excess of

* Committee. Ill. Eng. Soc., U.S.A. Report, No. 11, p. 31. "Automobile Headlights." See also Paper by P. G. Nutting, on "Brightness and Contrast in Vision," presented at the Tenth Annual Convention in Philadelphia, September, 1916.

tobacco the reds and greens disappear in the exact spot looked at, so that a pin head dipped in red sealing wax and another in green fail to be distinguished. This may come on with anyone, especially above middle age, who uses more than three ounces of tobacco weekly. It would affect all fine work, or the distinguishing of signals, or skill in sniping.

The centring of the eyes on the object looked at is accomplished so automatically that anything looked at should have its image fall on the macula. This is scarcely recognisable till actually tested, but if a certain small spot, say the dot of an "i" in a newspaper held at a foot distance, is carefully fixed by one eye, and *without moving the eye* from this fixation point, the number of letters clearly seen simultaneously is determined; it will be found that the area where vision is good enough to distinguish the forms of a newspaper type at a foot off, can be covered by a shilling.

In any exact vision then the eyes are constantly being centred on little spots like this, and the rest of the retina merely gives rough orientation.

This centring of the eyes means muscular adjustments so that the axes cut through the point looked at and is termed *convergence*.

In reading the eyes go along a line in a series of little jumps fixing a series of such spots in succession though not necessarily in contact, but sufficient to give hints of words, which the brain can use, and if the light is poor, or the image confused, or the text strange, greater exactness of fixation is required, which is the beginning of strain, causing the sense of one variety of glare.

Nothing has been said yet about the action of the iris, which contracts on exposure to light, and also on efforts at accommodation. With rapid variations it may be a cause of strain, and possibly is a main agent in the irritating effects of flicker, but the range of protection gained from adaptation must be thousands of times greater than any momentary effect from the iris. Apart from flickering variation of light any strain or discomfort through pupillary contraction can probably be neglected.

There is, however, another action in addition to the centring of the image on the macula by convergence, and that is the focussing of the image on the layer of rods and cones by the action of the lens. This is called *accommodation*, and is the only sense in which the word should be used, although it is not infrequently used when adaptation of the retina is meant. Accommodation is of considerable importance in the form of glare due to surfaces of low intensity, shiny paper and so on.

The exactly focussed image is as a rule the only one attended to, unless another image obtrudes, when difficulties and a sense of glare may become apparent.

Each object as looked at is focussed as clearly as possible on the retina. Accommodation is probably being varied all the time, as the eye, is not achromatic, and different coloured images overlap. Judgment is very deceptive here. The black posters of the Underground Railways give a good example. All the letters are in the same plane, but the slight excess and different amount of accommodation for focussing a red line makes it appear to be nearer in comparison with a green line, or the black surface.

From this cause one poster with an outlook from a tunnel on green fields and red roofs attains almost stereoscopic relief.

Effect of Chromatic Aberration.

For exact work the nearer the light to monochromatic the clearer the image. Some coloured glasses amber, chlorophyl and so on which cut down the extremes of the spectrum, certainly add clearness in the effort to focus the distance, as deer stalkers and others have found. Here too even in this chromatic accommodation we can find evidences of strain and glare.

I have recently been charting a certain series of records in which interpolation figures were set down in black, at first I did it without lines. One day to make my lists tidier I drew a series of vertical and horizontal columns with red ink, and in half an hour had a violent headache from eye strain. I tried black lines without trouble and also red lines with red figures with less trouble. It was obviously the extra work of focussing the red and black exactly which produced the sense of glare.

There are then these three main ocular mechanisms *Adaptation, Convergence*, and

Accommodation to consider in any lighting problems as regards the effect on the eye. These effects where (a) no immediate result is noticed may be grouped as strain, or (b) with immediate discomfort and inability to work, glare.

As I have said the eye usually works in quite an inexact way, just picking up rough hints. Any muscular actions are in the normal eye well within its powers. For instance accommodation is comfortably used to about one third of that possible, more can be used if necessary, but soon gives rise to fatigue and strain.

It is usually taken that with test type the image of two points or two lines at an angular distance of one minute can be discriminated, but Dr. Walter Lancaster* refers in a paper recently to stereoscopic observations which show discrimination of separation as low as 3 to 12 seconds, corresponding to an adjustment of the retinal image in thousandths of a millimetre.

The eye is never at rest, it roams over an object, picking up hints, or runs along a line of print, stopping five or six times to take up the meaning, but never maintaining a steady fixed effort for long. Yet it can establish the effort to thousandths of a millimetre if necessary. If an object is so fixed that in an attempt to get a clear image every possible adjustment is made, the utmost reserves have to be called up for this steadiness. Too poor an image on the retina seems the chief cause. Either the light is absolutely too poor or the contrasts insufficient, from retinal conditions, or from veiling through extraneous light, as from a shiny page.

During the period of growth nutrition is often seriously interfered with, and the part of myopia which is school or work produced is essentially due to these causes. Our own Committee suggested 2 foot-candles on every desk as the minimum requirement, but three would not be an unsatisfactory average for school children.

Chronic conditions of poor light and black surfaces set up the curious functional disturbance which passes into actual disease of the nerve centres from long continued strain, in what is known as miners nystagmus. Men who work in thick seams rarely get it, but when the eyes have to be strained in narrow seams it is common. Long before it is obvious the symptoms can be elicited by turning the eyes to look up and to one side, when the jerking tremor comes on.

The Absolute Glare Limit

Turning now to another aspect of glare that from bright sources—with every eclipse of the sun cases are recorded where individuals looking at the partially eclipsed sun without protecting glasses, receive permanent damage. The sensitive layer or the nerve structures about it are burned out functionally at the macula, and a permanent black spot remains on the field of vision. This represents the extreme case of glare from high intrinsic brilliancy.

After any bright object is looked at, the destruction of visual purple, and accompanying changes are so rapid and intense that time is taken up in the restitution of the original condition, and during this time after images occur. They should normally disappear in the fraction of a second, but with intense light, or with poor circulation in the eyeball, or certain depressed conditions of nerve structures, which may be quite temporary as from a bilious attack or more lasting from neurasthenia, these after images may persist to such an extent that glaring effects result. In this connection fatigue and excess of tobacco are always to be thought of.

Mere glare effects from continued images of the source of light in the field of vision may be quite exhausting. The Hall at the University of London where some educational conferences were held last month is a particular example of an extremely offensive lighting.

Apparently the maximum brightness which the eye is prepared for through its long course of evolution is the brightest sky, apart from the actual image of the sun. That nature has prepared us for this may be judged from the pigmentation of the eyes of southern as compared with their slighter coloration in northern races. This amount is generally taken as 2.5 to 3 candles to the square inch, and some such amount has been suggested as the standard for any visible sources of lighting.

* "Eye Strain, etc." Dr. W. B. Lancaster, New York Med. Journ., August 29th, 1914.

INDIRECT AND SEMI-INDIRECT LIGHTING.

Indirect lighting may accomplish this to perfection, but the semi-indirect can also be utilised if the actual incandescent source is used as a primary to light a sufficiently large diffusing shade which will act as a secondary source, which can be looked at steadily without hurt to the eye. Indirect lighting has its restfulness due to its diffuseness and absence of high intrinsic brilliancy on any surface. The eye is saved much fatigue by absence of violent contrasts, and by not having to pass from a comparatively dark surface to an incandescent one quite suddenly. On the other hand as it is only through shadows that objects are seen, comparatively shadowless lighting, whilst useful for general illumination apart from special eye work, or for examination of plain surfaces reading or writing, is not so useful where small objects or textural surfaces have to be examined. It would thus be good in a bank but bad in a school.

Direct lighting is the most economical method for handling objects or manufacturing processes, but there again if the light source is not kept out of the field of vision, or shaded down to the 3 c.p. per inch standard for any visible surface, it will cause strain and fatigue.

THE EFFECT OF CONTRAST.

The matter of contrast which comes in here, is of very great importance not only in regard to light sources which may be the cause of after images, and distribution of light, but also for such problems as the kinema screen. Excessive or defective contrast may be equally troublesome. The New York Committee * who investigated glare a couple of years ago stated that vision was best with contrasts about 1 : 20, but was possible at 98 : 100, and could be done without discomfort up to 1 : 100. In sunlit scenes out of doors, excluding the sun itself, the contrasts rarely exceed 1 : 20. Indoors not over 1 : 200, although window frames against a bright sky may give a contrast 1 : 10,000. They thought it probable that the comfortable limiting ratio lies between 1 : 100 and 1 : 200 and preferably should be kept below 1 : 100.

This appears to me an important suggestion. It seems to take into account the admitted fact that a bright object is more distressing to the eye when presented with a dark background, than if seen amidst relatively bright surroundings owing to the adaptation of the eye ; in full daylight with an eye adapted to relatively great brightness, even an incandescent filament may not appear very glaring, whereas in the dark a lighted match, held near the eyes, produces temporary dazzle.

The factor 1 : 100 appears to have been suggested mainly by practical experience.

It was suggested in Prof. L. Weber's contribution to the discussion on glare in 1910 and now receives a measure of official support by being put forward by the Committee of the American Illuminating Engineering Society. It would, however, be more satisfactory if detailed physiological evidence in support of the ratio could be obtained in the laboratory and this appears to be a matter on which the Society might well initiate investigations.

PRACTICAL ILLUSTRATIONS OF EFFECT OF CONTRAST.

Even in cases where the surfaces are of moderate brightness and no extreme form of glare would be imagined to exist an extreme contrast, or a contrast operating in the wrong direction, may be inconvenient. An instance in point appears to be furnished by the discussion on the Lighting of Rifle Ranges before the Society in 1915. The view was generally expressed that to many people a brightly lighted white target with a dead black background gave an acuteness of vision inferior to that obtained when the surroundings were illuminated with subdued illumination. This appears to be a case where a fixed ratio of brightness between illuminated object and surroundings would be desirable. Similar effects are met with in stage lighting, and in the cinematograph theatre, to which reference will be made shortly. It seems questionable whether the practice of keeping the auditorium of a theatre in complete darkness is desirable. In some cases the continued fixation of a brightly lighted spot on the stage, with the rest of the field of

* I.E.S. Amer. Report, No. 12, "On Glare," 1914–15, p. 37.

view in complete darkness, entails a strain on the eye.

The fixing of a desirable limit to contrast has also a bearing on local illumination. It is hardly possible to lay down the law that either "local" or "general" lighting is invariably best; but the extreme contrast present when a workman is engaged on fine work, and using a powerful shaded light operating over a small area, with the surroundings in complete darkness is undoubtedly trying. Here again a limit to the contrast might well be prescribed.

This raises one other question. Should there be also a limit to uniformity? The view is often expressed that completely uniform lighting, (were it attainable), would also be trying to the eyes. Is extreme monotony of brightness also objectionable? This is a matter on which very little physiological evidence is available but there seems ground for the belief that the best conditions involve an illumination on the object viewed greater than that given to the surroundings. The Committe of the Society on school lighting recommended an illumination of the blackboard in excess of that provided generally in the room. It is, at all events, generally agreed that when the contrast is *reversed*, *i.e.* when the illumination on the work or object viewed is actually less than the general illumination the visual effect is prejudiced.

Illumination of Test-Type.

These problems have also a relation to the illumination of the test-type used by oculists for the examination of eye sight. In cases where the examination is of a rough character the requirements may be met by stating that the card should be "well illuminated," and the contrast between card and surroundings will not be severe in an ordinary room. But for accurate work, and particularly where records are made over long intervals of time, it might be useful to have a standard method of lighting complying with the following conditions.

(1) Uniform illumination on the test card of known value, not less than 3 foot-candles.

(2) No naked sources of light visible in the room.

(3) Minimum contrast of 100 : 1 between card and surroundings.

(4) Progressive measured variation in illumination of card, and of contrast between black letters and background, from high to low values.

(5) Facilities for repeating tests by white, red and green-blue light.

Requirement (4) would be particularly useful in detecting and recording for comparison cases of "night-blindness" in which the degree of contrast perceptible is much reduced at low illuminations. A closer study by oculists of methods of graduating and measuring conditions of illumination under which tests are carried out might have a material effect on precision of testing defects of vision, and it would be helpful if a compact standard form of apparatus complying with the above requirement could be designed.

Illumination for Distant Objects.

It may be added in passing that while the illumination needed for close work is fairly well understood, the conditions for relatively distant vision have been less studied. For example there is general agreement that for reading good type on white paper 2—3 foot-candles is the minimum desirable. But the corresponding illumination required for lighting targets, blackboards and illuminated signs and notices to be viewed from a distance has been little studied. Assuming that the angle subtended by the detail at the eye, and the contrast between this detail and the background are the same, would the illumination necessary be different according as the object is viewed at a distance of say 1, 5 and 20 and 100 feet? Probably it would be considerably greater.

Again if we assume that 2—3 foot-candles is needed for close observation of good type on a white background how far will higher illumination enable us to perceive fine detail which cannot be clearly seen at the above illumination? And to what extent will a higher illumination aid us in perceiving detail if the contrast is less than that presented by black letters on a white ground? An investigation, on practical lines into these matters would yield results and might have an important bearing on the question of the

amount of illumination necessary for different classes of work in factories.

GLARE FROM "SUCCESSIVE CONTRAST" AND FLICKER.

The effects of glare discussed above are due to simultaneous contrast. A corresponding effect occurs when the eye sees surfaces of vastly differing brightness in succession. For example when we pass from a brightly lighted room into the darkness outside, the eye being adapted to the brilliancy inside, can see little until it has become adjusted to the lower brightness. The present darkening of London offers many examples of this effect. The alternate patches of brightness under lamps and darkness between them are doubtless distracting to drivers and pedestrians whose eyes are required to adjust themselves to the altered conditions as they pass from one region to another. This is an argument in favour of more uniform illumination.

An extreme instance of such an effect is met with in the case of a flickering, unsteady illumination which is notoriously trying to the eyes. Flicker is rather a mysterious subject, which would require separate treatment. It seems more evident to the peripheral retina than on the macula, and is due to alterations in light and shade slow enough to evoke continual efforts at adjustment. It is in this respect perhaps that the pupillary contractions of the iris are most to be regarded. This effect might also receive the attention of the Society though it is obviously more difficult to specify as it includes both time and brightness. It should not, however, be impossible to specify the steadiness of sources of light and to state approximately the amount of flicker which is distinctly perceptible to the eye and therefore objectionable. Such fluctuations may occur either on a fluctuating gas supply or an electric lamp run off an alternating supply of low frequency. With alternating current the point at which no flicker is perceptible depends on the damping effect of the filament and the duration of an impression on the retina. This is attained in about 1/20th of a second in average light and 1/5th of a second in very bright light. If the frequency exceeds 50, as is generally the case there should be in general no perceptible variation in the case of stationary objects. As mentioned above the brightness of the light is a material factor. Therefore it is conceivable that an effect which is inappreciable if one looks straight at the filament might be detected if one is observing an illuminated object of much lower brightness.

As is well known inconvenient effects may be produced by moving objects illuminated by alternating arcs. At a certain period of revolution rotating machinery may even appear stationary, an obviously dangerous effect. This method of lighting should not be employed for the illumination of moving objects. The corresponding effect of electric incandescent lamps on alternating supply is very much less, but might in some circumstances be appreciable.

In some circumstances peculiar stroboscopic effects may occur even when the source of light is steady. In a cinema picture, for example, one may notice a rapidly travelling motor car whose wheels are either at rest or moving backward. This is due to the time interval of rotation between two spokes being a multiple of or slightly less than the interval between two pictures. Possibly it would be cured by putting a prominent patch of whitewash on one spoke.

CONDITIONS IN CINEMATOGRAPH THEATRES.

Flicker at once calls up the much debated question of cinematograph displays. In itself this is a harmless form of amusement, and for educational purposes has undoubtedly great possibilities. In the case of grown up people, whose attendance is entirely a matter of choice any possible prejudicial effect is of less consequence than in the case of children, whose eyes and minds and physique are in the process of development. If cinema displays should become a regular feature in schools, and attendance obligatory, it is evident that all possible care should be taken to avoid any possible injury, while, even in the case of ordinary entertainments there is perhaps a danger that too frequent indulgence in the pastime might have bad results.

The question of the effect of such entertainments on the mind hardly falls within

our province. We are, however, concerned with the effect on the eyes, and particularly the conditions that should be observed in the lighting of screen and auditorium generally.

In the first place it should be observed that the constant fixed direction of the eyes in a dark adapted condition is unusual. With the eyes steadily fixed one looks at a distant landscape without trouble, but fixing on a relatively near object may soon give rise to strain. One can test this very easily by watching an electrically controlled clock outside a building for the half minute jerk forward; the effect on the eyes soon becomes appreciable. The question of the length of such entertainments for children therefore deserves attention, and the practice, which I believe, at one time was prevalent, of remaining in the hall and seeing the same series of films over and over again should not be allowed. Even for grown up people the duration of such entertainments is often too long. If the majority of the spectators have normal vision they should see clearly at any distance over 20 feet without effort. Any shorter distance of the screen means effort of both accommodation and convergence and in the case of children owing to their short undeveloped eyeballs that effort is much greater than in adults.

Where there is any indistinctness of the picture the spectator may make efforts to see more clearly, and if less than 20 feet from the screen these efforts are useless, as all images, whether apparently near or far, are on the screen in the one plane.

The best position visually would be from 30 to 50 feet from the screen and on a level with its centre. Raising of the eyes above the horizontal should be eliminated so far as is possible. The strain on the superior rectus muscle which raises the eyeballs very easily causes headaches, as in the notorious academy headache. The screen therefore should be as low as possible.

Where the screen is much foreshortened as when seen from the sides of the hall in front, the efforts to correct the distorted image are very fatiguing and children should be excluded from such seats.

The question of controlling the perfection of the film and the skill of operators is doubtless a difficult one. Certainly the freedom from flicker varies considerable in different classes of halls. I believe that in the cinematograph industry, as in others, there is a progressive circulation of materials from the highest class halls to the lowest. The worst film I ever encountered was one that had migrated to Iceland.

On the question of lighting there is room for experiment but we are in a position to make more definite suggestions :—

(1). *Illumination of the Screen.*

The illumination of the screen will be found to vary from 0·5 ft. candles to 1 foot-candle or more. It has been suggested that the standard value should be fixed at a minimum of 1 foot-candle. The illumination of screens is easily tested and it should not be difficult to arrive at a reasonable value by observations in typical halls.

(2) *Material for the Screen.*

This is essentially a matter for experts. I believe it is generally agreed that a good matt-white screen gives the best effects. Screens composed of aluminium powder have been introduced on account of the greater brilliancy attainable, and consequent economy in the consumption of light. Such screens, it is said, are apt to give rise to inequalityof brightness according to the direction from which they are viewed, and to inconvenient moving shadows. As they are still in the experimental stage it would perhaps be better not to adopt them for entertainments for children.

(3) *Illumination in the Theatre.*

Extreme contrast between the brightness of the screen and of the general surroundings is objectionable. The ratio of 1 : 100 already suggested would imply brightness of surroundings of, say, not less than 0·01.—0·02 ft. candles. In practice this value can easily be attained. A certain amount of illumination on the seats has also been considered desirable to enable people to find their places. A value of 0·2 to 0·5 ft-candles has been suggested for this purpose. By careful design it could be probably be arranged that the provision of this extra illumination would not materially affect the bright-

ness of the screen and would therefore not impair the image.

Any lights or illuminated notices indicating exits, etc., should be carefully screened so that their brightness does not exceed 3 c.p. per square inch. This is ample for the purpose in view but not high enough to cause glare.

The illumination in the theatre should be controlled by dimmers so that it can be gradually diminished before films are shown, thus avoiding the painful effect on the eyes of suddenly switching on and off the full illumination.

The illumination in corridors should have a value intermediate between that outside and in the theatre. An illumination on the floor of 0·5 ft. candles would be sufficient. Here again all lights should be shaded. The convention employed in the early Tube days namely that going towards green lights leads to safety or exits, and that departing from red lights indicates the same precedure, might be adopted.

In this paper I have tried to bring before you a number of aspects of lighting, where the effect of light on the eye requires further study. On many of them more detailed information is required and it is to be hoped that the discussion will be instrumental in stimulating inquiry into them.

DISCUSSION.

The PRESIDENT (Sir Wm. Bennett), in opening the discussion, said that they had all been much interested in Dr. Kerr's paper, and appreciated the very lucid manner in which he had explained certain anatomical and phsiological details connected with the eye—the strange behaviour, for example, of the retinal rods and cones, and of other weird things concerned in the working of this wonderful machine—a knowledge of which was essential for the better understanding of his communication.

The importance of proper methods of lighting generally is receiving more attention in these days, which was largely due to the work of the Society. Probably the most important of all the questions affecting proper lighting were those of glare, flicker and contrast, about which something further would no doubt be said in the ensuing discussion.

From the popular standpoint, the part of Dr. Kerr's paper dealing directly with kinema displays would doubtless attract most attention. Since the introduction of this form of entertainment there had no doubt been an increase in eye-trouble, headache, and brain-worry amongst children frequenting such entertainments. It was not an uncommon thing to hear that a child "likes the picture shows, but they often give him a headache." He also understood that vomiting sometimes followed a visit of young children to the pictures.

Many people were greatly concerned about the tendency to moral harm in childhood of these entertainments, whilst the liability to physical harm was apt to be overlooked—or at all events not to be estimated at its true value. At the present time it was seriously suggested that an age limit should be placed upon children in this connection—a suggestion which should receive support from everyone interested in sight welfare. The eye, which, after all, is for practical purposes an off-shoot of the brain, is, like all other organs, vulnerable and easily deranged during the period of development. The earlier the stage of development the more vulnerable it is—hence the great importance of Dr. Kerr's remarks concerning the effect of kinema glare and flicker upon the eye and brain of young children; this tended not only to impairment of eyesight but to brain worry and instability, and so might contribute to the liability to moral harm.

The HON. ASSISTANT SECRETARY (Mr. J. S. Dow) then referred to a number of letters received from the Chairman of the Cinema Commission (the Right Rev. Bishop of Birmingham), and others, expressing their interest in Dr. Kerr's paper, and regretting inability to be present.

Contributions to the discussion had also been received from Dr. Ernest Clarke, Mr. N. Bishop Harman, Mr. Colin

Bennett, and Mr. E. G. Kennard as follows :—

Dr. ERNEST CLARKE, M.P., F.R.C.S. : I have very little comment to make on Dr. James Kerr's excellent paper on "The Effect on the Eye of Varying Degrees of Brightness and Contrast." There is no doubt about the truth of his statement that extreme contrast between the brightness of an object and that of the general surroundings is most objectionable—in fact, it is absolutely painful to some people. Shrinking from the glare of light (for which I have had to invent a word, viz., photaugiaphobia, to distinguish it from the shrinking from ordinary light, *i.e.*, photophobia) has had of late years many more victims, probably due to sources of artificial light not being properly masked, nor properly diffused.* Naked incandescent or electric light should never be fixed on the eye line, but should be placed high up or low down, and then carefully shaded. The best form of illumination is a reflected electric light, but unfortunately the cost of this and its extravagance militates against its general adoption.

I agree with Dr. Kerr's remarks with reference to the cinematograph. Where flicker occurs it is, of course, extremely harmful. If trouble occurs in the better cinema where the flicker is absent, it is probaby due to the presence of astigmatism, which ought to be corrected with the proper glasses, or, as Dr. Kerr remarks, to the screen being too glary and the auditorium too dark.

Dr. Kerr's remarks with reference to the position of the screen and the person looking at it, are especially useful. There is no doubt that those sitting near to the screen get considerable eye-strain from the raising of the eyes, and also from the unnecessary accommodative effort, and I consider that under these circumstances no one should be allowed to look at a cinematograph screen nearer than 20 feet. The best position is in a gallery at the opposite end of the room.

Some people who can read a book with unglazed paper quite easily, suffer immediately from eye-strain with *glazed* paper.

Finally, there is one important fact we must not lose sight of. In our attempt to remove glare by diffusing the light, we must beware of lowering the light to such an extent that the illumination is not sufficient for our purpose, because in this latter case we introduce eye-strain.

Mr. N. BISHOP HARMAN (*communicated*): I have been greatly interested in reading the proof of Dr. Kerr's paper on "The Effect on the Eye of Varying Degrees of Brightness and Contrast." Whether we live in the spacious times of unlimited evening illuminations of our towns, or in these days of darkness, the state of the streets of our big cities is proof positive that very little thought has been given to the attainment of a system of illumination which will be both effective and comfortable. In pre-war days the exposure of flaming arc lamps in rows in front of shops at very little above the level of the heads of the people was distressing to a high degree. No less troublesome, and much more dangerous is the bewilderment caused by the innumerable twinkling lights that surround one in the passage of a great darkened square or street. Trafalgar Square is a terrible place on a dark clear night when there is no haze to distribute the rays of the lights or deaden those at a distance. That such a state of affairs is quite unnecessary is proved by the recent changes in the street lamps in Marylebone. The effect of which is to reduce the specific intensity of the light, increase the luminous surface, and produce a delightfully soft glow at once illuminating and comfortable.

In the interests of traffic this change, involving the elimination of unduly bright sources of light, and violent contrasts in bright and dark areas, is welcome.

It would seem doubtful policy to attempt the prescription of any specific standards of lighting for general purposes. Minima are necessary; but minima should not be allowed to become our maxima. The one thing that should be insisted upon is the relative illumination of the parts of the same place. Dr. Kerr has wisely insisted upon this as the chief factor for comfortable vision. I know of no more fatiguing exhibition than

* See a contribution from the writer to the *Medical Press and Circular*, August 4th, 1915.

that of the optical lantern, whether it be with fixed pictures or with the cinematograph. The fatigue is produced by the exposure of the eyes to what is but a low degree of actual illumination, but one that is relatively high in the darkened surroundings of the screen. There is no real necessity for this excessive contrast. I have known lecture rooms in which the whole proceedings were carried out in the full light of day, and yet in these rooms, without any alteration or shading of windows or skylights, effective use was made of the optical lantern for lecture purposes. The arrangement was as simple as it was effective. The screen was fixed in the darkest part of room and surrounded with a deep black frame projecting forwards at right angles to the surface of the screen on all sides. I have seen the same plan adopted to make railway signals visible to drivers who approach them from the darkness of the tunnel. In the full light of the open space they would be invisible, but framed in this fashion the light can be picked up with ease.

If, as is quite possible, the cinematograph should be introduced into schools for education purposes, some such arrangement for a daylight exhibition would be of great value. It would reduce structural alteration to a minimum, do away with blinds that get out of order so easily, and prevent fatigue from excessive contrast.

Mr. COLIN N. BENNETT (*communicated*): First, I wish to express my gratitude to the Hon. Secretary of the Illuminating Engineering Society for his cordial invitation to me to be present at the reading of Dr. Kerr's paper on the "Effect on the Eye of Varying Degrees of Brightness and Contrast." It is a great disappointment to be prevented by reasons of health from being present.

With almost all of the lecturer's remarks I am in full agreement. In one instance I should go farther than he does. The damage to eyesight resulting from the present practice of continuing kinema seating right up to within ten feet or so of the screen—especially where the hall is broad for its length—must be considerable, even for adults. I know of halls in London where the spectators in the front, second and third rows of seating, and in seats near the end of the rows, have to view the screened picture at an oblique angle of from twenty-five to thirty-five degrees with the picture plane. This is all wrong, and reflexly must do great damage to the industry itself.

The remarks upon arranging for a graduated diminuation of illumination between the outer vestibule of the kinema and the actual picture hall, also upon the necessity for providing and making use of dimmers for raising and lowering hall lights between pictures, seems to me highly important.

When it comes to dealing with the question of flicker brought about by the action of the rotating projector shutter, I think it might well be borne in mind that with the modern three-blade rotary shutter there are forty alternations of light and darkness upon the screen in each second of time, that is practically the same number as when burning a twenty-five cycle A.C. arc lamp in the open. In other words, at normal screen illumination flicker is quite unnoticeable.

Again, in considering the relation of eye-strain to discernment of fine detail, while a well-focussed projected kinematograph pict re should be, and can be, quite sharp, in the sense of not being woolly or "fuzzy," it will n t by its nature present any very fine detail to tax the resolving power of the eye when viewed from a reasonable distance, since the degree of enlargement of the original film picture (from under one inch in diameter to from twelve to twenty-four feet in diameter) has the inevitable effect of producing wide broad massed lights and shadows. These are admitted by artists to be the most restful to the eye.

The eye of a spectator of a kinematograph picture viewing a projected full size upon a sixteen foot screen, from a distance of fifty feet, is subtending an angle of view of about sixteen degrees, or a full picture angle in the artistic sense.

The spectator who watches a twenty-two foot picture from a distance of a hundred feet subtends a view angle of eleven degrees, still by no means so narrow an angle as to be fairly called a condition of concentrated light. Also, in a moving picture, the macula of the

eye is not fixed upon one point of the screen all the while, but is kept moving slightly in a natural way with the movement of the characters or incidents of the picture.

With Dr. Kerr's discreet hint that at present the general intellectual level of the public kinema performance is not all it might be I am personally in full agreement, but the way to improve this is not, as some social reformers seem to think, by insisting upon the inclusion of a patchwork of disconnected, and in themselves "scrappy," so-called educational films, in what sets out to be an amusing picture programme.

On one point I do not agree with the lecturer. He evidently favours the compulsory illumination of kinema halls during the picture performance. Where this is attempted the result is to suffuse the hall with light of a widely differing tint from that of the arc light upon the screen. More or less of this light finds its way to the screen, and if it does nothing worse, invades the shadow portions of the image which take to themselves a more or less ruddy, or alternately a washed-out tone. You now have two lights of differing tint opposing one another upon the projection screen, and as a result, the want of chromatic correction of the eye feels it, and eye-strain and a glare effect are rapidly induced. If the picture hall itself is decorated in shades of lightish brown and red, it will reflect quite sufficient of the light coming from the screen picture to afford a satisfactory illumination.

I should like to add a word for the picture operator in his operating box or room, constantly subjected to eye-strain from the naked arc light, and from the light spot on the film in the gate, which by the nature of his calling he must watch continually. There are nearly ten thousand operators and assistant operators employed in picture theatres in Great Britain, and the compulsory use by them of viewing glasses or spectacles passing only light from about the region of the spectrum D to $E\frac{1}{2}F$ would be a very quick and practical means of helping to save human eyesight.

Dr. Kerr is much to be thanked for the thorough-going way in which he has taken up the science of kinema lighting from the point of view of benefitting the public.

Mr. E. G. KENNARD (*communicated*): I am sorry to be unable to be present at Dr. Kerr's paper, but enclose a few remarks on the subject of lighting in cinematograph theatres.

With regard to flicker, this has been largely eliminated in modern projecting apparatus by the use of the three-bladed shutter. The first shutter comes into operation to mark the change in the screen of succeeding impressions on the film, the other two shutters being placed equidistant from the first shutter, so as to cut the light off twice in succession while any one image is showing on the screen. The old arrangement only provided one shutter to cut the light off while the actual moment movement of the film took place.

Increased speed of projection also largely reduces flicker. "Jumping" on the screen (not to be confused with flicker) is found by some persons to be very annoying to the eyes. This is more noticeable at a short distance from the screen. The trouble is chiefly encountered with old films where the "sprocket-holes" have become worn.

With regard to the illumination on the screen even greater variations than that of 0·5—1·0 ft.-candles have been found to exist in any one subject. The usual practice in the operating room of a cinema theatre is to run at a constant current somewhere between the limits of 50 and 90 amperes, according to the size of the picture. It is much more difficult than is generally appreciated to maintain a steady arc with a heavy current and with the crater in the correct position, so as to give good illumination results. It is not therefore an easy matter to regulate the amount of light to correspond with the varying densities of the film. As it is also practically impossible to get enough light to show a dense film with a good screen-illumination, any attempt to work out to a definite value of screen illumination, within narrow limits, would not be successful.

The presence of smoke and fog in the hall also makes a large difference in the

screen illumination, especially in a long building where the operating room is situated at the opposite end to the screen.

Dr. Kerr's remarks on metallic screens are borne out in practice, as the result is very unsatisfactory when the film is viewed from an angle.

Dr. C. W. KIMMINS (L.C.C. Chief Inspector of Schools) said that there was now in the Illuminating Engineering Society a body in a position to give expert advice in regard to illumination, and it should therefore be possible to incorporate this experience into bye-laws which would go a long way towards removing the prejudicial effects of cinema exhibitions on the eyesight of children. In this way it should be possible to render all such places harmless, or comparatively harmless from this point of view for people of all ages.

He hoped that Dr. Kerr would come before the Commission which was now dealing with this subject and give evidence with regard to some of the points dealt with in his paper.

Mr. A. E. NEWBOULD, speaking on behalf of the cinematograph industry, expressed the hope that the result mentioned by the last speaker would be arrived at with the assistance of men like Dr. Kerr, Mr. Harman and others. That would be doing a real service to the cinematogroph, of which it was badly in need. As to the moral question that had already been mentioned, there had been suggestions in regard to certain improprieties which had been attributed largely to the amount of darkness prevailing and regulations had been imposed to the effect that every portion of the auditorium must be clearly visible from any other portion. There was such a variety of officials in different places charged with the duty of seeing that this regulation was carried out, and such a variety of interpretations were placed upon the meaning of it, that it was almost impossible to carry on the industry and to satisfy the authorities. Therefore if it were possible to arrive at a formula for some standardised form of lighting which would not materially affect the value of the picture on the screen the trade would welcome it and gladly comply with a regulation which could be universally applied.

He had a message to convey from the Cinema Commission to the Society. First, he was to ask Dr. Kerr if he would give evidence before the Commission, and second, he was to invite the Society to nominate some suitable members to form part of the Committee charged to arrive at the desirable results which he had outlined, and which the last speaker had expressed. As a member of the industry who had a very large stake in it he would be only too glad to give every possible assistance.

Mr. F. W. GOODENOUGH (Chairman of the Council) promised that at the next meeting of the Council the question of the formation of a small committee to co-operate with the Commission in the manner indicated by Mr. Newbould would be considered.

He felt sure that the Society could do no more useful work than to assist in bringing about the establishment of reasonable and practical regulations for the lighting of cinematograph theatres.

Dr. F. W. EDRIDGE GREEN said that for the past twenty-five years he had considered it a fundamental principle of lighting that in order to see well with the centre of the retina the periphery must be stimulated. It was absolutely necessary that this physiological principle should be complied with in the cinema theatre, and therefore that there should be a reasonable amount of illumination in the auditorium without interfering with the picture on the screen.

It was chiefly in the poorer-class cinema theatres that flicker was noticeable and headaches prevalent; he had noticed that a number of such theatres had been obliged to close, presumably on the principle of the survival of the fittest. People who found themselves affected in the manner described stayed away or went elsewhere.

While he cordially agreed with the facts mentioned in Dr. Kerr's paper he took exception to some of the physiological explanations. There was no evidence whatever to show that the rods were light percipient organs, and this view was now expressed in leading text

books on physiology. The retina must be regarded as a liquid photograph, the impression being created by the action of light on the visual purple.

Mr. E. T. SWINSON said that in London the theatres most patronised by children were the poorer ones where least provision was made for lighting or position. This was largely a question of finance so far as the position of the seats in respect to the screen was concerned, and he knew many a theatre in London where it was not unusual to find thes seats within 4 ft. or 6 ft. of the screen. Furthermore, the screen was at such an angle that it was impossible for the children to see the pictures properly even in most favourable circumstances.

Added to that was the fact that in this class of cinema the films used had already gone through various stages of use, and by the time they reached them were in the worst possible condition. Mr. Newbould had mentioned that the lighting question was now being tackled. That might be so in London, but he was not sure that similar instructions had been given with regard to provinicial theatres. In London the rule had been laid down that the theatre must be fairly well lighted. That had been done from the moral aspect, but incidentally it should also be possible to secure the result mentioned in the paper.

It was admittedly a difficult matter to apply a golden rule to theatres of this description, of whatever class and wherever they might be situated. It seemed to him, however, that the Commission might very well lay stress on the point that any regulation with regard to lighting cinemas should not come from the local authorities but direct from the Home Office, which had powers to make regulations standardising the minimum amount of light which should be provided in the auditorium.

Lieut. S. R. MULLARD, R.N.V.R., asked if Dr. Kerr could give any idea of the average time interval required by the eye to adapt itself from intense glare to darkness and vice versa. It was a matter in which he personally was very much interested because he had done a great deal of work in which very high power lamps were used and had found that the contrast in coming out of the laboratory in which arc lamps were burning, into the obscurity outside was so great that it took some minutes for the eye to adapt itself to the altered conditions. They made it a rule in the Ediswan laboratory that all very bright lights were switched off half an hour before the staff left the laboratory. Otherwise accidents might occur owing to the contrast of the darkened streets.

The matter was of interest with reference to the light source in the cinematograph lantern. The eye strain was unquestionably greatest when the ordinary arc lamp flickered or went out and restarted. In a large measure the flicker accounted for the variation in screen illumination.

He confidently hoped that before long these difficulties would be overcome by the introduction of a high candlepower "Pointolite" lamp for use in at least the smaller cinema halls, in place of the existing arc lamp. This new lamp, like the 100 candlepower lamp of similar construction, would be easy to operate and would give a perfectly steady concentrated source of light.

Mrs. M. A. CLOUDESLEY BRERETON said it was an important fact if, as stated, the films in the poorer-class cinemas were practically worn out. She hoped the Commission would make a note of that. It was, of course, a question of finance, but this should be the last direction in which an attempt should be made to save money, and there should be some very stringent rule made that after a certain period all films should be scrapped.

The second point she wished to refer to hinged on that. Some of the journalists present would remember that they were received a short time ago by Mr. Acland at the Imperial College of Science, and they were asked to interest the general public in the relation of science to industry.

The subject for discussion furnished an excellent example of a case in which the general public were vitally interested in the applications of science. It was particularly necessary to bring such matters to the notice of the workers of the country, and journalists could aid

in making them widely known. If the Society could assist towards bringing about useful by-laws eliminating conditions in cinema theatres which were prejudicial to health it would do most useful work.

Mr. A. CUNNINGTON referred to the need for more precise definition of intrinsic brilliancy, as one of the factors causing glare. In the discussion on glare, which took place before the Society in 1908, a definition of intrinsic brilliancy was given in terms of candle power per unit of area. But area of what? He understood that the projected area of the light source was meant. Prof. Morris apparently acted on this assumption in presenting his figures last year in connection with the half-watt lamp, but he was not quite sure himself that it was necessarily the projected area which should be taken.

In the case of illuminants, which consisted of a fine mesh of incandescent substance, it was impossible to distinguish the bright elements with the naked eye. The question arose, therefore, how the intrinsic brilliancy of metal filament lamps and gas mantles should be rated. Ought one to take the projected area enclosing the incandescent material, the actual glowing area itself, or a figure making allowance for the dark spaces between incandescent filament or fibre?

Mr. J. G. CLARK, speaking on the question of uniformity in lighting, mentioned an experience in connection with a factory where the men habitually moved about with their work from place to place in the shops in order to get a change of intensity of light. In the same way, workmen had expressed a preference for movable lights so that they could vary the intensity of the light according to the work they were engaged upon.

With regard to the 3 candles per square inch mentioned in the paper, would the author in his reply make it clear how that was related to the position of the light to the eye. For instance, in the case of the meeting hall of the Royal Society of Arts, the average brilliancy was higher than 3 candles per square inch but the lamps were sufficiently out of the range of vision not to cause any trouble. It was a question that involved the angle of glare, *i.e*, the angle at which the line of glare should meet the eye.

Some four or five years ago, Mr. Mackinney and himself read a paper before the Society in which one of the illustrations showed a series of sources of light with shades and globes showing against dark and light backgrounds. The sources of light that appeared quite glaring against the dark background were by no means glaring against the lighter background. It showed that we must not be too close in our ideas as to permissible intrinsic brilliancy. Mr. Cunnington had referred to the mantle as a woven mesh. It was true that it was a mesh but if the mantle were looked at under a microscope it would be seen that the places where the meshes would be were filled with tiny fibres projecting from the fabric of the mantle, and these fibres, being fine, became intensely brilliant when the mantle was incandescent and practically filled up these meshes with light. Another effect that operated was that through the meshes could be seen the light surfaces of the mantle on the inside. The inside of the mantle was incandescent as well as the outside, so that the mantle had practically become a solid source of light. Thus, so far as the mantle was concerned there was question that the projected area represented the true intrinsic brilliancy.

Mr. A. P. TROTTER, referring to intrinsic brilliancy, said that some years ago he suggested before the Society that in dealing with intrinsic brilliancy, especially, with a metal filament lamp, they must not take a micrometer and measure the filament cold. That was not what was seen when the lamp was burning. By irradiation, the filament was ten times or more the width as measured cold, and that was what should be taken if anything at all were taken for measuring the area of the surface. But he did not know that we could have different figures like that: it would be necessary to take something like a total area surrounding the lamp and that was a very difficult thing to put into words. In any event, we must not take a micrometer measurement of the filament and say that that was the area.

There was a point with regard to school lanterns and screens. About 20 years ago he arranged a screen in a lecture room at Cape Town, and although he could not remember where he got the idea from he placed the screen up in a dark corner of the room in such a manner that practically the windows were not visible from it, and made the screen of transparent cloth—there was no better material than tracing cloth—and by placing the lantern behind the screen it was possible to work in daylight without the blinds pulled down and to see excellently. These methods seem to present distinct advantages when room was available for projection from behind the screen.

Mr. J. W. BARBER said that to arrange for the lighting of the auditorium of a cinema and at the same time not to interfere with the lighting of the screen was a somewhat difficult matter. The result of a lighter auditorium was a weaker picture, so naturally if an effective screen result be required any increase of auditorium lighting must be accompanied by a corresponding increase in the illumination of the picture. The two matters were therefore conflicting. It has been suggested that the standard value of screen illumination should be fixed at one foot-candle, but apart from the conflicting factor mentioned it must not be overlooked that certain points of projector construction have a bearing on the apparent illumination of the screen. The cinematograph projector is fitted with a revolving shutter, the obscuring arc of which varies very much in different makes of machines. Two machines may be working side by side and, leaving out any question of film density, one machine may easily require 25% more current to obtain an equal brilliancy of picture. He felt therefore that unless some consideration be taken of the shutter efficiency of the projector no formula would be equitable. Yet again the density of the film played its part, the density naturally varying according to the nature of the subject. He thought these practical difficulties, which necessitate intelligence on the part of the kinematograph operator, would almost prevent arriving at a standard value for the luminosity of the screen.

Regarding the permanent lighting of the auditorium, a considerable amount of time had been spent on an endeavour to arrive at a formula, as mentioned by Mr. Newbould, but it had been found very difficult to arrive at any figure that would satisfy everyone. The question of side lighting came into play, and if in a wide hall the lighting be increased to give some standard minimum of illumination in the centre portions, those patrons sitting at the side of the hall might be prevented from comfortably viewing the picture. He did not think there was any necessity to fix any figure for the illumination for the centre portions of the hall as during the projection of a picture, which in a modern cinema is but momentarily interrupted, the centre of the hall is fairly well illuminated by the beam of light from the lantern.

On the question of the distance from which a picture might be viewed without harm to the eyes he felt that no fixed figure could be taken without consideration of the screen dimensions. Figures of from twenty to thirty feet have been quoted as being the minimum distance anyone should be permitted to view a picture, but he had personally found that looking at the screen a distance away equal to its width no eye strain at all was suffered. Dr. Kerr made the interesting remark that should a certain small dot of an " i " in a newspaper be held at one foot distance and carefully fixed by the eye it would be found that the area, where vision is good enough to distinguish the form of the surrounding type, can be covered by a shilling. It occurred to the speaker that the question of the distance from which the screen might be viewed, without eye strain, could be worked out with these figures as a basis, remembering, however, that the eye did not attempt to cover the whole screen but merely concentrated on the animation of some particular object.

Mr. J. S. DOW said that although much of the discussion had turned on cinematograph theatre lighting, the principles referred to in Dr. Kerr's paper had a very wide application.

The recognition of the part played by adaption of the eye had led to a revision of

our ideas of glare. He would like to see a detailed examination of the effect on capacity to see variations in light and shade, of variations in the brightness of the surrounding area. This would be a most useful piece of work, and would go far towards establishing the correctness of the suggested limiting ratio of 100 : 1.

In this connection he would like to make one enquiry, although he was afraid it would be difficult to give an exact reply. It was interesting to notice that minimum, the variation in brightness that could be just perceived by the eye (for example in a photometer) was approximately 1 in 100. Was there any direct relation between this value and the ratio of 100 : 1 which seemed to be the limiting contrast which the eye could comfortably sustain ?

He had made a number of measurements of the illumination of cinema screens and found that one foot-candle was a usual value. As regards Mr. Kennard's comments on this point he thought it should be made clear that the illumination specified should be obtained on the screen from a clear aperture, before the insertion of the film. If this value could be standardised it would go far towards securing good results. It was a question, however, whether too great a screen-illumination might not be as detrimental as too little, both by causing glare and by causing any flicker to be more readily perceptive.

The provision of a certain amount of illumination in the auditorium, without spoiling the image on the screen, required study. It should not be impossible, by proper direction of the light, to prevent rays straying on to the screen. By the aid of modern illumination-photometers all such matters could now be easily tested when any particular scheme was being tried.

Mr. L. GASTER said that he had much appreciated Dr. Kerr's paper, with its happy blend of physiological knowledge and insight into lighting problems. The effect of excessive contrast, as Dr. Kerr had remarked, had entered into many questions before the Society. For example, it had a marked bearing on the conditions of lighting in schoolrooms, where it was recognised that the illumination on the blackboard should exceed that for general purposes. Similarly in the factory it was now agreed that, generally speaking, very strong local lighting, with complete darkness in the surrounding area, was objectionable. One good feature of the minimum general illumination recommended in the Home Office Report was that it prevented excessive contrasts occurring in this class of work.

The conditions in the streets also furnished a good example of the objection to alternations of bright patches of light and obscurity. The changes now being introduced in the Metropolitan area, which would eliminate to a great extent the patchiness complained of, marked a great advance in this respect. It was to be hoped that after the war authorities would learn from present experience and be more ready to consider methods of diminishing the glare from very powerful lamps.

He also agreed with much that had been said on the subject of cinema lighting. Dr. Kerr had emphasised a most important point in drawing attention to the danger of eye-strain and the effect of continually gazing upwards, on children occupying the front seats. The minimum distance of children from the screen should certainly be specified.

He also agreed that in the case of children the duration of the performance should be limited. Another point to be noted was that grown up people understood what was conveyed by a picture much more easily than young children. In the case of the latter any want of clearness due to poor illumination or defective films was therefore particularly objectionable as imposing a strain not only on the eyes but on the mind. For the same reason he advocated that in the case of a young audience some preliminary explanation of the subject should always be given.

All these points were of special consequence in view of the great potentialities of the cinematograph as an educational medium. In the event of the bioscope becoming more widely used in the schools, the conditions should be very carefully supervised.

He also wished to support the Chairman of Council in welcoming the suggestion that a small committee of the Society

should be formed to co-operate with the Cinema Commission in regard to proper lighting for screens, halls, &c. The Society had already formed standing committees on School and Library Lighting, which worked in co-operation with School Authorities and the Library Association. A similar commitee to deal with cinema lighting could easily be arranged, and the Council would doubtless be glad to render any assistance in this direction.

Dr. J. KERR, in replying, said the speakers had almost entirely confined themselves to cinema lighting, which he had taken as an illustration of the occurrence of strain and glare in the unadapted eye, or rather the dark-adapted eye, and where there were still great possibilities of improvement.

The glare of shops and of the streets was more serious as a general problem than the cinema, and one which might involve questions of accident, even of life and death. For that reason he had urged that a standard of three candles per square inch of illuminating surface should be the maximum permitted, wherever the eye had to encounter the light directly. The ideal of lighting seen in the glare and blaze of the Great White Way, with its blinking and eclipsing signs, is a fatiguing horror, offensive alike to aesthetics and hygiene.

The transition of retinal adaptation in passing from brightness to dark is quite slow, may go on for an hour or two. Although practically it is complete in half an hour, for some minutes, at any rate, the individual is almost blind from want of retinal sensitiveness. Transferred now with the eye adapted for dark and highly sensitive to a bright blaze, there is a slight protection through the almost instantaneous contraction of the pupil, which effort causes a sense of glare whilst it is fully maintained, until with adaptation of the retina in a minute or two it again relaxes.

Turning again to the cinema, on which there have been so many interesting points presented in discussion, especially as to the mechanism of the picture production. The machinery is a highly technical part which he left out of consideration, and taking the average screen brightness as one foot candle suggested that an additional light could be usefully employed in the auditorium, not merely for convenience, but also to prevent extreme dark adaptation, and contrast glare from the screen, or from turning up of lights. He had sat through a university lecture in Munich in the ordinary daylight, a lantern in a darkened room behind projecting microscope slides on the screen without any failure in appearance. The decoration of the auditorium should be graded from brightest to darkest near the screen. The screen itself might have some further screening at the sides and top. There should be indirect lighting from the back part of the ceiling, and no illuminating source other than the screen coming into the field of vision. Such details are largely matters of cost, and their feasibility can be usefully worked out by the Committee of the Society, which has been suggested.

The speaker was not one of those who think that the cinema has a great future as part of our ordinary educational apparatus. It is capable of useful application for research in the analyses of rapid changes and complicated movements, but its popularity with children is simply as a mental dissipation. It gives emotional stimulus without much effort. It is mainly destined to be a recreation and amusement, capable of harm if improperly used, but which should also be maintained as one of the pleasures of life, and made as refined and hygienic as possible.

The HON. SECRETARY made a few general remarks, expressing the indebtedness of the Society to Dr. Kerr for his Paper, and thanking the President for presiding at the meeting, despite the many claims on his time at the present moment.

In conclusion, the PRESIDENT announced that the next meeting would take place at 5 p.m. on Thursday, March 22nd, when a discussion on "Fluorescence and Phosphorescence and their use to produce Luminous Effects." would be opened by Mr. F. Harrison Glew.

THE LUMEN.

By A. P. Trotter.

The subject discussed at the last meeting of the Illuminating Engineering Society was the Lumen. I wish to add some remarks to those which I made on that occasion. The Lumen may loosely be called a unit of light. Scientifically it is the unit of luminous flux—I am inclined to agree with F. W. Willcox that it should be regarded as a quantity of light rather than an illuminating power or value. In the first place it is necessary to understand what the term is intended to connote, and then to define it carefully.

I may claim some acquaintance with the drafting of definitions. I was chairman of the nomenclature sub-committee of the British National Committee of the International Electrotechnical Commission. That nomenclature committee consisted of men of very diverse qualifications. One would prevent us from confusing a cut-out with a fuse, another guided us to distinguish between mutual induction and the coefficient of mutual induction another had strong views on load-factor but no effectual meeting was possible unless Dr. Silvanus Thompson was present. On that committee I learned all that I know about scientific definitions.

Some of the terms which we defined are in common use in engineering, but where they are loosely employed, definition is advisable. Others, like "efficiency" have been borrowed from ordinary language and have been given very precise scientific meanings; and others like "barretter" convey no suggestion whatever of their interpretation. Sometimes a definition, if it is to be within reasonable limits, can be understood only by those who are already acquainted with the subject, *e.g.*, magnetic susceptibility. We have now before us the term Lumen, and we are told that lamp-makers are going to reject the ancient but strictly Anglo-Saxon expression candlepower and that Lumen will be substituted in their price lists. A definition must be framed and we must consider whether we need follow the obscure academic phraseology of the new generation of American writers or whether words can be found which shall satisfy a scientific man, and may be used by an ironmonger's assistant to explain a Lumen to a Member of Parliament.

Prof. J. T. Morris gave a definition by which one of those who took part in the discussion was misled in two ways. That speaker thought that the length of a foot was a factor and that you can consider "Lumens in the direction you are using it." Mr. Willcox is very helpful, though he begins in a ponderous way. He says that the Lumen is strictly defined as the unit of Luminous flux, luminous flux being radiant power evaluated according to its visibility. (An elephant may be defined as a proboscidean pachydermatous mammal. A far better definition is: a square animal with a leg at each corner and a tail at each end.) After quoting this pedantic American definition he says in plain language that the Lumen is the unit quantity of light flowing from a lamp or luminous source. He does not add that the lamp should be half as large as a lump of chalk, but leaves the magnitude to imagination. Later on he "admits," though he has not suggested otherwise, that the Lumen is a pure numerical function of the mean spherical candlepower. Some people will wonder what an impure one would be like, and others will shy at "function" and fear that dI/dt is coming. But at last, stowed away in a parenthesis, we find the crisp statement: "the Lumen=12.57 times the mean spherical candlepower." This, of course, is not intended for a definition of a Lumen, but means that the number of Lumens emitted by a lamp is 12.57 times the mean spherical candlepower. as he clearly explains elsewhere.

That is plain enough. But the commercial man will say: "Why 12·57? Why not give $4\frac{3}{4}$ per cent. discount and say a dozen?" The explanation is that we are not considering the intensity of light emitted in any one direction as in the idea of candlepower, but emission of a quantity or a flood of light in all directions over the surface of a sphere. These last

six words may not seem to be necessary, but they are needed to carry on the argument. The surface of a sphere of one foot or one inch or one arm length's radius is 12·57 square inches or square feet on square arm lengths.* We may afterwards slice the sphere into zones, but the primary idea is the sphere.

Here we are tempted to forsake Mr. Willcox and to adopt the definition proposed by Prof. J. T. Morris, and say that the Lumen is the flux of light received by a surface of one square foot, and having an illumination over its area of one foot candle. But this is a corollary rather than a definition. I think it is a mistake to confuse taking with giving, reception with emission. In my book on "Illumination" I fell into the opposite error of writing that the illumination *produced by* one candle at a distance of one foot is one foot-candle. A foot-candle should be defined as the illumination received perpendicularly on a surface at a distance of one foot from a source of one candle-power.* It is a good thing to bring in the idea of reception when speaking of illumination, but if the Lumen is to take an early position in our list of photometric magnitudes and units, we must not allude to the foot-candle too soon.

Having accounted for the appearance of the numeric 12·57, it does not seem necessary to bring in 4π. Even if we explain that π means 3·14159 and is the measure of the circumference of a circle of unit diameter we have a long way to go to show how the surface of a sphere is calculated. A definition should contain as few terms as possible requiring explanation, but it may make assertions which are not self-evident. Dr. Silvanus Thompson* deduced from the American definition that one Lumen was $1/4\pi$ of the whole light emitted from a spherically uniform source of light giving one candle in every direction.

Working on this, we may substitute 0·0795 for $1/4\pi$ and take 0·08 as near enough for practical purposes, and omit the words "spherically uniform," since they are implied in what follows. This brings us very close to Mr. Willcox's parenthetical definition, and we may say that *one Lumen is 0·08 of the whole light emitted from a source giving one candle in every direction.* Some such word as "quantity" is needed. Dr. Silvanus Thompson used "the whole light"; the academic expression of the text book and lecture room is "flux of light."

The question will next be asked:—"Why not candlepower?" Putting aside the difference between an intensity and a quantity, the answer is: "Candlepower is a measure in only one direction; in many lamps very different candlepowers are emitted in different directions; the Lumen gives a sort of average." An intelligent man will at once form in the back of his mind an idea of what we call mean-spherical candlepower, and he will say: "Why not state the average candlepower?" Why not, indeed? This is rather a puzzler. Prof. J. T. Morris gives what is probably the trade reason, namely that a lower rating would have to be admitted, and an ordinary so-called 16 candle-power lamp would give 12½ average candle-power. Mr. Willcox as a trader does not allude to this climb down, but after announcing by a head-line, "Lumen *versus* spherical candlepower," says that mean spherical candlepower is a mouthful, is too cumbersome, and its abbreviation M.S.C.P. is more or less cryptic.

Let us be frank. Let us say that we really mean the average, but by multiplying by 12·57 we obtain a unit which readily lends itself to, and simplifies the calculation of illumination.

It should also be explained that what is really wanted is illumination, which is measured in foot-candles, and that, as Mr. Willcox suggests, if a floor is to be illuminated,

$$\frac{\text{Floor area in sq. ft.} \times \text{foot-candles}}{\text{Net lumens per lamp with its shade}}$$

gives the number of lamps required for that floor.

* Fleming has shown that the factor for reducing the horizontal candlepower of a vertical straight parallel filament lamp to mean spherical candlepower is $\pi/4 = 0{\cdot}7854$. The M.S.C.P. of a 16 c.p. lamp is therefore 12·57, and this multiplied by 12·57 is 158. The lumens emitted by a straight parallel filament lamp are therefore 0·875, say ten times the horizontal candlepower.

* This gets rid of the word "falling" which I used in *The Illuminating Engineer*, Vol. VII. p. 341.

* *Illum. Eng.*, Vol. VII., p. 351.

THE LUMEN AS A MEASURE OF ILLUMINATING POWER.

By PROFESSOR A. BLONDEL.

I HAVE read with great interest the contributions of Professor J. T. Morris and Mr. F. W. Willcox, whose references to my work I gratefully acknowledge. The latter has treated the question of the use of the Lumen in a manner so very clear, complete and persuasive that he does not leave a great deal to be said by those who support his views. The impression I have received on reading his remarks leads me to hope that he will succeed in convincing those engineers who have not yet appreciated the utility and practical convenience of the Lumen.

Professor Morris has also brought forward very clear and convincing arguments, and his comment regarding the inconvenience of the mean spherical candlepower for sellers of electric lamps is well worth consideration.

As Mr. Willcox kindly recalls, my proposals in regard to this matter were made more than twenty years ago.* I hope readers will bear with me, while I review some recollections of the first steps in the development of the now well-established unit, the Lumen. In 1893 I was first interested in the subject in the course of my experience in light-house work, which led me to regard the conception of flux of light as a matter well deserving investigation. I then formed the opinion, to which I still adhere, that this is the *only* basis on which the characteristics of electric projectors can be properly understood and their relative illuminating value adequately represented.

I subsequently found, in studying street lighting, that it was of considerable practical utility to work with flux of light, which can be measured as the product of the illumination and the area of surface illuminated. This aspect of the matter attracted the attention of Mr. John Hesketh, Electrical Adviser to the Queensland Government, who took the trouble to translate and publish in *The Electrician* two contributions which I had myself published on this question in 1895*.

Those who are sufficiently interested to look up these contributions will find that I discussed not merely the conception of the flux of light, but the definition of the Lumen; also that I described an instrument termed a "Lumen-meter," and designed for the direct measurement of the flux of light from a source. The methods then described are identical with those now generally adopted for the rapid calculation of the average illumination on large surfaces in rooms and streets, and are based on a knowledge of the flux of light derived from various types of lamps.

In the first of these contributions I proposed to adopt the Lumen and the lumen-hour as practical units. Unfortunately at the time when these ideas were first publicly presented they appeared premature. The scientific and technical education of engineers had not reached the present stage; it had not yet become usual to determine the polar curves of lamps in the laboratory and to present the results in an industrial form similar to that illustrated in Mr. Willcox's paper.

Thanks to the late Prof. Hospitalier's able support the International Electrical Congress of Geneva (1896) officially accepted the "lux" and the "lumen" and the Laboratoire Central d'Electricité, under the direction of Prof. Paul Janet, has, from that time up to the

* Mesures de l'Intensité lumineuse moyenne sphérique (*l'Eclairage électrique*, 1895); Unités Photométriques (*l'Eclairage électrique*, 1895, translated in *The Electrician*, 1895; Rapport sur les unités photométriques au Congrès Photométrique international de Genève, 1896; Théorie des projecteurs électriques (*Industrie électrique*, 1894), &c.

* l'Eclairage public par les lampes à arc (Part I. *Génie Civil*, Part II. *Revue Technique* Paris, 1896; translated in *The Electrician*, Vol. XXXV., p. 816, *et séq.*).

present, employed these units in all tests on arc lamps.

New units only slowly become familiar, and in this case were handicapped by the unfortunate inspiration which led the German engineers to create a "Hefner Lumen," having as its base the Hefner unit of intensity.

Illuminating engineers owe a debt of gratitude to the American Illuminating Engineering Society for having taken up this question in such a systematic manner during the last few years, and presented through its Committee on Nomenclature and Standards such a lucid series of reports. In the most recent report interesting additions are made to the system of units, notably the adoption of the "lambert" as the convenient unit of brightness; I myself recently proposed to complete the series of units by the "phot"—a unit of special interest in view of the fact that the milliphot is almost equal to the foot-candle.

The definition of the "phot" and the "lambert" has only become practicable since our friends in the United States selected the centimetre instead of the metre as the unit of length in photometry.

The Lumen has thus been brought before the notice of engineers in a continually improving form, and I have no doubt that the discussion of the Illuminating Engineering Society will be successful in removing the last objections and in convincing English engineers of the desirability of simplifying photometric measurements and placing illuminating engineering calculations on a sound and scientific basis.

Moreover, as I have shown in the contributions referred to above, it is very interesting to profit by the analogies between the photometric system of units applied to the study of distribution of light, and the units employed in the solution of problems relating to magnetic and electro-static fields.

Thanks to the happy agreement between the three national laboratories in England, France, and the United States on a common international unit of light, these three nations will eventually impose the international candle and Lumen on the rest of the world: even should the Hefner Lumen continue a separate existence it is easy, by the mere use of a numerical coefficient, to pass from one system to the other and thus render comparable the results presented in all countries.

The introduction of the "Half-Watt" lamps furnishes an additional argument in favour of the adoption of the Lumen. I myself have several times experienced disagreeable surprises in purchasing such lamps, anticipating a certain horizontal candlepower and subsequently discovering that the rating referred to candlepower in a vertical direction. It is desirable to avoid all such confusion by rating lamps in terms of their luminous flux.

For all these reasons I hope that the discussion now in progress will induce my English friends to adopt the proposals of the Illuminating Engineering Society in the United States, which have already received a most favourable reception in France and have now also received influential support in England.

CORRESPONDENCE.

THE DEFINITION OF THE LUMEN.

SIR,

The full discussion on the Lumen as a Measure of Illuminating Power in the last issue of the ILLUMINATING ENGINEER does not leave a great deal to be said on this subject. The arguments put forward in the Editorial remarks in that issue * are, from a scientific standpoint, very weighty and cover the ground pretty fully.

There are, however, several points in connection with the definition of the lumen, and its popularisation, that require to be made clear.

First it should surely be recognised that the choice of units and framing of definitions is essentially a scientific

* *Illum. Eng.*, Jan. 1917, pp. 2—4.

matter, and, as stated in the Editorial referred to, should be determined with a view to the future and the needs of a science, and not in deference to the "man in the street." It is therefore important that those engaged in the search for a suitable definition of the lumen should be quite clear whether they are attempting to frame a scientific definition, or merely drafting a convenient method of conveying the relation between lumens and candlepower for popular use.

In my opinion, the strictly scientific and final definition is best not attempted as yet. For the time being it is necessarily based on the international candle, and the latter must first be defined in any system of units. At present it appears best, therefore, to define the lumen as the flux of light emitted by one candle, operating over unit solid angle; and to add as a corollary, when defining the foot-candle, that a lumen is equal to the flux of light received by an area of one square foot illuminated with an intensity of one foot-candle. These two definitions are mutually consistent. There is not the least doubt as to the meaning of the lumen. Its value is unaffected by the choice between the foot and the metre as the unit of length, but naturally depends on the unit of candlepower adopted (now the same in Great Britain, France and America).

As regards popular explanation, there are two distinct objects to be achieved. We should state in round numbers the numerical relation between the average candlepower and the lumen, and makers of electric lamps may follow this up by pointing out that for ordinary metal filament lamps the value in lumens is roughly ten times the former candlepower (horizontal) rating.

We should not, however, stop after defining the numerical relation. With a view to the future it is most desirable that people generally should understand the conception of flux of light and should realise that flux, being the product of candlepower and a solid angle, is something different from candlepower alone. There is some danger that mere numerical ratios, especially when coupled with a reference to point-sources, or sources radiating uniformly in all directions, would foster incorrect ideas regarding the lumen. It might be assumed, for example, that rating in lumens available from a lamp could be only accurately applied when one was dealing with a point of light, and with uniform radiation in space. This of course is not the case. The great advantage of lumen-rating is that it is independent of these limitations.

Numerical relations, therefore, must be supplemented by explanations of the nature of the lumen, and, to my mind, the easiest way to approach this matter is by proceeding to the second alternative definition of the lumen in terms of a surface one square foot in area receiving one foot-candle. To this might be added a series of practical examples.

I lay stress on this point because there is already a tendency to assume that the change to lumen-rating merely means using average candlepower, but multiplying it by the factor 12.57. When we pass to the applications of lumens to calculations we realise at once that the change goes much deeper than this; and that it is dictated by fundamental scientific considerations and not only by the fact that it happens now to be a convenience to lamp-makers in enabling them to cut adrift from the delusive unidirectional rating. The change is desirable as a convenience to illuminating engineers and is supplementary to existing methods of rating lamps in terms of watts or gas consumption.

I am, etc.,

AN ENGINEERING CORRESPONDENT.

RATING OF ELECTRIC LAMPS: TOTAL WATT-RATING AND LUMEN-RATING.

SIR,

With reference to the discussion on the use of the lumen in rating electric lamps I should like to correct one misconception that appears to be prevalent, namely, that rating in lumens means the exclusion of watt-rating.

The fixed practice of rating in total watts has been found very satisfactory and it is not proposed that this will be discontinued. It is merely proposed that where specification of luminous values is desired, these should be expressed in lumens instead of in candlepower, this avoiding the misunderstanding resulting from uni-directional rating in candlepower. Rating in lumens is thus supplementary to total watt-rating. The whole question was discussed before the Illuminating Engineering Society in 1915. *

Yours, etc.,

F. W. WILLCOX.

* *Illum. Eng.*, April, 1915.

OBITUARY.

PROF. DR. FRIEDRICH ERISMANN, OF ZURICH.

From a recent copy of the "Zeitschrift für Schulgesundheitspflege," of which he was editor for a dozen years, we learn of the death of Prof. Dr. Friedrich Erismann, of Zurich.

Professor Erismann was a contributor to the proceedings of the Illuminating Engineering Society, and took part in the discussion on the Natural Lighting of Schools in 1913. He was born in 1842, the son of a Swiss pastor. He originally intended to work as an ophthalmologist, and took for his degree thesis a work on toxic amblyopia. Settling in Petrograd in 1869, he became interested in myopia and its causes, and from this to hygiene in general, becoming one of the first authorities on school hygiene. He was invited to the Chair of Hygiene at Moscow in 1881, and there established a laboratory from which issued many papers on ventilation and illumination.

He published about 140 papers, half in Russian, dealing mainly with artificial lighting and its effects on the atmosphere, shadows and their results, the distribution of lighting, and the orientation of buildings. He had strong opinions on the hygienic value of indirect illumination, recommending it for school use, the minimum standard for school which he suggested was 2·5 foot candles.

Finally, in 1894, he settled at Zurich, where he identified himself with all kinds of hygienic progress till his death at the age of 73.

We note with regret the death of Sergeant A. Lawton-Jones, who was killed in action on September 8th, in his twenty-third year. His commanding officer stated that he was always ready to do his duty, and more than his duty.

Mr. Lawton-Jones was a member of the Illuminating Engineering Society, and was formerly in the employ of the General Electric Co.

He will be greatly missed by his colleagues.

We understand that Mr. E. A. Nash, who was formerly associated with the Faraday House Electrical Engineering College, is now serving with the Colours as a Sub-Lieutenant in the Royal Naval Volunteer Reserve.

PROFESSOR S. A. RUMI.

Our readers will learn with regret of the sudden death of Professor S. A. Rumi, who passed away on January 8th, at the age of 64 years. Professor Rumi was an active Corresponding Member of the Illuminating Engineering Society, and took part in a number of discussions on photometry and lighting problems.

In his own country he was well known in electrical circles. Born at Novara in 1853, he graduated at the Turin Polytechnic at the age of 21, and was afterwards appointed Professor at the Physical and Technical Institute of Sassari. He subsequently collaborated with Prof. Pacinnotti in some of his experiments, and ultimately migrated to Genoa, where he became President of the Ligurian Section of the Associazione Elettrotecnica Italiana.

He had wide interests and was associated with many other scientific bodies and took a prominent part in the International Electrical Congress at Turin in 1911.

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General Manager.

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

Standing Committee on Glass and Optical Instruments.

The Advisory Council of the Government's Department of Scientific and Industrial Research have added to the list of their technical Committees a Standing Committee on Glass and Optical Instruments. The membership of the Committee is at present as follows :

Professor H. Jackson (Chairman), Mr. Conrad Beck, Professor C. V. Boys, F.R.S., Mr. F. J. Cheshire, Mr. A. E. Conrady, Mr. A. S. Esslemont, Mr. J. W. French, Dr. R. T. Glazebrook, F.R.S., Sir Howard Grubb, F.R.S., F.R.A.S., Mr. E. B. Knobel, F.R.A.S., Dr. T. R. Merton, Professor J. W. Nicholson, D.Sc., Captain Creagh Osborne, R.N., Mr. H. J. Stobart, Mr. J. Stuart, Mr. M. P. Swift, Mr. William Taylor, Mr. F. Twyman, Lt.-Col. A. C. Williams, Mr. W. F. J. Wood,

The Committee met on December 11th and, having regard to the urgency of the problems requiring investigation in respect of these essential industries, appointed a series of Sub-Committees to which various special problems were referred. Among these problems the more important are :—

(A) Raw materials for glass and glass making ; (B) Optical properties of a large range of glasses ; (C) General physical and chemical properties of glass and glassware for scientific and industrial purposes; (D) Testing and standardising of glassware ; (E) Workshop technique ; (F) X-ray glass apparatus ; (G) Optical calculations and lens designing ; (H) Optical instruments ; (J) Translation of foreign works on Optics.

This brief description indicates certain lines of investigation which have been brought forward. The Standing Committee does not propose to limit itself to these subjects but is prepared to consider and report upon the necessity for investigation in other directions, relevant to its terms of reference. Manufacturers who have experienced difficulties requiring investigations for their solution in connection with the subjects of glass and optical instruments, or who desire to make suggestions for special researches on these subjects, are invited to communicate in the first instance with the Secretary of the Research Department, Great George Street, Westminster, S.W., who will direct the correspondence into the appropriate channels for attention.

BOARD OF SCIENTIFIC SOCIETIES.

Report of Committee on National Instruction in Technical Optics.

A sub-committee, consisting of Mr. Conrad Beck, Mr. F. J. Cheshire, Mr. E. B. Knobel, Sir Phillip Magnus, Prof. H. Jackson, and Prof. A. Schuster, has issued a Report emphasising the urgency of better facilities for instruction in technical optics. Years must elapse before the full results of any steps now taken will be realised.

Optical processes and manufacture are of direct interest to many branches of science. While it may be impracticable to evolve a complete organisation for the study of the subject at once, steps should be taken immediately to meet immediate requirements and to cover the transition period.

The chief suggestions in this direction set out in the Report of the sub-committee are as follows :—

(1) The appointment of a supervising representative Council.

(2) The appointment, under the proposed supervising Council, of an administrating Director with special duties during the transitional period, which will include advice to the trade and the organisation of the different parts of the curriculum.

(3) The translation of suitable works and the abstracting of other important publications on Technical Optics.

(4) Pending the erection of a suitable building the organisation of day and evening classes at the Northampton Institute, and arrangements for higher instruction at some other institution of University rank.

ERRATA.

Illuminating Engineer, January, 1917, p. 7, column 1, line 8 : *For* "Mr. Harry E. Jones, Chairman of the newly-formed National Gas Council," *read* "Mr. Harry E. Jones, President of the newly formed National Gas Council."

P. 34, column 2, line 9 : *For* "The suggestion had also been made that lamps might be most useful . . . ," *read* "The suggestion had also been made that lamps might be marked in lumens per watt. This would be most useful . . . ."